

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TWO-WAY BIOSPHERE-ATMOSPHERE INTERACTIONS: THEIR IMPLICATIONS FOR SATELLITE OBSERVATIONS OF REGIONAL LAND COVER CHANGES

FINAL REPORT

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This final report describes accomplishments of the project (NAG5-8617) (1999-2002): "TWO-WAY BIOSPHERE-ATMOSPHERE INTERACTIONS: THEIR IMPLICATIONS FOR SATELLITE OBSERVATIONS OF REGIONAL LAND COVER CHANGES".

(1) PROGRESS IN THE FIRST YEAR

Significant progress has been achieved during the first year of this project. A new zonally-symmetric model of the coupled biosphere-atmosphere system was developed and validated by comparing to observations. This model not only includes representation of atmospheric dynamics but also new representations of biospheric dynamics. The region of West Africa has been selected as the focus of our research. The atmospheric model is zonally symmetric, and includes representation of atmospheric dynamics, a radiation scheme, a moist convection scheme, a boundary layer scheme, and a cloud parameterization scheme. The biosphereic model is the Integrated BIOSphere Simulator (IBIS), which includes representation of the water, energy, momentum, and carbon balance, vegetation phenology, and vegetation dynamics. We modified the representation of canopy hydrology in IBIS to account for the impact of rainfall sub-grid variability. The biospheric model and atmospheric model are separately tested against observations. The synchronously coupled model is then used to simulate the biosphere atmosphere system of West Africa.

(2) PROGRESS IN THE SECOND YEAR

Significant progress has been achieved in the second year of the project. The new model has been used to study climate equilibria of the coupled system, long-term natural variability of the coupled system, and response to local anthropogenic forcing as well as remote oceanic forcing. Using a synchronously coupled biosphere-atmosphere model which includes explicit representation of ecosystem dynamics, we show that the equilibrium state of the model is sensitive to initial vegetation distribution. This modeling result supports the existence of multiple climate equilibria. Using the same model, further experiments are carried out to investigate how the coupled system responds to non-permanent vegetation perturbations. Our results demonstrate how transitions between different climate equilibria can take place when governed by the two way biosphere-atmosphere feedback. These findings advance our understanding regarding the mechanisms of climate variability over West Africa. The results of these studies are documented in the several publications that are listed in this report.

(2) PROGRESS IN THE THIRD & FOURTH YEAR

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During the third year, we continued our efforts in this project towards understanding the two-way biosphere-atmosphere interactions. Some of our efforts focussed on the improvement of the representation of land surface hydrology in climate models, in particular the role groundwater aquifers in providing the lower boundary condition of the system. We also looked at the role of sub-grid heterogeneity in shaping the dynamics of biospheric processes at large scales. The third area of investigation involved coupling the biosphere-atmosphere model to a mixed ocean model and investigation of the dynamic behavior of the coupled biosphere-atmosphere-ocean system. We also investigated the role of small scale topographic variability in shaping the African savanna. Another area of investigation was the role of the biosphere in the mid-Holocene climate over West Africa.

During the fourth year we continued some of our efforts on the improvement of the representation of land surface hydrology in climate models, in particular the role groundwater aquifers in providing the lower boundary condition of the system. A Doctoral student (Pat Yeh) was funded to finish his Doctoral research on the representation of groundwater aquifers in climate models. Another Master student (Yeonjoo Kim) was supported to work on the role of micro-topography in shaping Savanna environments.

PUBLICATIONS

Kiang, J., and E. A. B. Eltahir, 1999. The Role of Ecosystem Dynamics in Biosphere-Atmosphere Interactions over the Coastal Region of West Africa, *Journal of Geophysical Research*, 104(D24), 31,173-31,189

Wang, J., E. A. B. Eltahir, and R. L. Bras, 2000. On the Impact of Observed Deforestation on the Mesoscale Distribution of Rainfall and Clouds in Amazonia , *Journal of Hydrometeorology*, 1, 267-286.

Wang, G., and E. A. B. Eltahir, 2000. Biosphere-Atmosphere Interaction Over West Africa: 1. Development and Validation of a Coupled Dynamic Model, *Quarterly Journal of the Royal Meteorological Society* , 126 (565), 1239-1260

Wang, G., and E. A. B. Eltahir, 2000. Biosphere-Atmosphere Interaction Over West Africa: 2. Multiple Climate Equilibria, *Quarterly Journal of the Royal Meteorological Society*, 126 (565), 1261-1280.

Wang, G., and E. A. B. Eltahir, 2000. Ecosystem Dynamics and the Sahel Drought, *Geophysical Research Letters*, 27(6), 795-798.

Wang, G., and E. A. B. Eltahir, 2000. Role of Vegetation Dynamics in Low-Frequency Variability of the Sahel Rainfall, *Water Resources Research*, 36 (4) 1013-1021.

Wang, G., and E. A. B. Eltahir, 2000. Modelling the Biosphere-Atmosphere

System: The Impact of Sub-Grid Variability in Rainfall Interception, *Journal of Climate*, 13, 2887-2899.

Irizarry-Ortiz, M. M., G. Wang, and E. A. B. Eltahir, 2003. Mid-Holocene Climate over West Africa: Role of the Biosphere, *Journal of Geophysical Research*, 108 (D2): art. no. 4042

CONFERENCE PRESENTATIONS

Wang, G. and E. A. B. Eltahir, 1998. Biosphere-Atmosphere Interactions: Representation of Sub-Grid Spatial Variability of Rainfall Interception, EOS, Transactions of the American Geophysical Union ; Vol. 79, No. 45, page F349.

Eltahir, E. A. B., 1999. Mechanisms of Biosphere-Atmosphere Interactions over West Africa, Abstracts of the International Workshop on West African Monsoon Variability and Predictability (WAMAP), Dakar, Senegal, 1-4 June 1999, Page 40.

Wang, G., and E. A. B. Eltahir, 1999. The Role of Ecosystem Dynamics in Biosphere-Atmosphere Interactions over West Africa, Abstracts of the International Workshop on West African Monsoon Variability and Predictability (WAMAP), Dakar, Senegal, 1-4 June 1999, Page 78.

Wang, G., and E.A.B. Eltahir, 1999. Deterioration of the Natural ecosystem Induced by the Man-made Land Cover Changes: The Importance of Vegetation Dynamics, Transactions of the American Geophysical Union ; Vol. 80, No. 46, page F91.

Eltahir, E. A. B., 1999. Dynamics of Biosphere-Atmosphere Interactions over West Africa, Fall Meeting of the American Geophysical Union, San Francisco.

Eltahir, E. A. B., 2000. Hydroclimatology of West Africa, AGU Fall Meeting, San Francisco.

Irizarry, M, and E. A. B. Eltahir, 2000. A Study on the Climate of West Africa During the Middle Holocene Using a Zonally Symmetric Biosphere-Atmosphere Model (ZonalBAM), AGU Fall Meeting, San Francisco.

Yeh, J.-F., and E. A. B. Eltahir, 2000. The Representation of Groundwater Dynamics and Sub-grid Heterogeneity in a Land Surface Scheme, AGU Fall Meeting, San Francisco.

Eltahir, E. A. B., 2001, Elements of a Land-atmosphere Interaction Theory, *Transactions of the American Geophysical Union* ; Vol. 82, No. 20, page S102.